STATION PAPER NO. 83
AUGUST 1960

European Pine Shoot Moth Damage as Related to Red Pine Growth

By
Herman J. Heikkenen
and
William E. Miller

LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

European Pine Shoot Moth Damage as Related to Red Pine Growth

by

Herman J. Heikkenen
and
William E. Miller

Station Paper No. 83
August 1960

Lake States Forest Experiment Station
Forest Service
U.S. Department of Agriculture

CONTENTS

	Page
Methods	2
Evidence on insect populations	3
Population levels late in the generation	4
Population levels early in the generation	4
Minimum growth of undamaged trees exposed to attack	5
Conclusions	11
Literature cited	11

European Pine Shoot Moth Damage as related to Red Pine Growth

By

Herman J. Heikkenen
and
William E. Miller

It is a common belief that once a very young red pine planting becomes infested by the European pine shoot moth (Rhyacionia buoliana (Schiff.)), the insect population will build up in 3 to 5 years and cause serious damage to the pine (3, 5, 11).

Three years of extensive observations by the writers, however, have shown that plantations may harbor an infestation throughout their early years and suffer no serious damage whatever; also that plantations damaged during this period may recover and resume normal growth. The purpose of this paper is to bring out (1) that the shoot moth does not always build up and cause damage, (2) that damaged plantations may recover, and (3) that rapid height growth of red pine is associated with reduced susceptibility to shoot moth damage.

The authors are entomologists on the staff of the Lake States Forest Experiment Station, Forest Service, U.S. Department of Agriculture. They are headquartered at the Station's East Lansing Research Center, which is maintained in cooperation with Michigan State University.

Methods

The data presented in this paper were collected in eight red pine plantations typical of many seen in Michigan and northern Ohio. All were currently infested by the shoot moth. The plantations ranged in age from 8 to 17 years from planting and had been infested within 3 years after planting. Six were in Ottawa, Wexford, and Oceana Counties, Mich., and two in Carroll County, Ohio. The period of infestation was determined by dating old shoot moth attacks (7).

In the four youngest plantations, island-like groups of undamaged trees ranging in extent from about 1/10 to 1 acre occurred amidst large areas of severely damaged trees (fig. 1). The term "undamaged" here means that at least 90 percent of the trees exhibited straight, uninterrupted height growth. In two of the four remaining plantations, damage had never occurred (fig. 2); and in the other two, both in Ohio, the trees had recovered from severe damage (fig. 3).

To measure tree growth and insect damage in the first four plantations, two adjacent plots, each containing 10 trees on the same one-quarter or smaller fraction of an acre, were laid out. One plot of the pair was in an undamaged group of trees while the other was in an adjacent area of heavily damaged trees. In each of the remaining plantations, 10 trees on a $\frac{1}{4}$-acre plot were measured. The internodal distance and type of growth abnormalities in the main stem on these trees were recorded for each year of tree age.

Figure 1.--This 9-year-old red pine plantation has been infested with the European pine shoot moth for 8 years. Yet "islands" of lightly damaged trees exist (left), which are adjacent to heavily damaged trees (right).

Figure 2.--These red pines are 13 years old and have been infested with the European pine shoot moth for 9 years. No damage has occurred.

Figure 3.--This 12-year-old red pine plantation was seriously damaged by the shoot moth from 1950 to 1954, but has resumed normal growth.

Evidence on insect populations

Available evidence, described in the next two sections, indicates that damaged and undamaged trees in the same plantation were equally subject to infestation. Larval and pupal counts from previous years suggest that enough insects were present to infest every tree and leader in these plantations. Egg counts show that many eggs were laid on undamaged as well as damaged trees. Also, it is unlikely that the behavior of the shoot moth in these plantations was any different in the 2 or 3 years preceding the population counts which started in 1957.

Population Levels Late in the Generation

Damaged and undamaged trees in the same plantation were close enough to one another to be equally subject to infestation. In three of the four youngest plantations containing small groups of undamaged trees among large areas of damaged trees, population-level data were available in the form of number of insects (late larval and pupal stages) per damaged tree: Insect counts on damaged trees had been made once or twice in 1957 and 1958. These counts, averaging 27 + 9 insects per damaged tree per plantation, represent "medium" to "heavy" infestations on a subjective scale. In two plantations in Ohio, population-level figures from 1952 and 1953 were available (11). These averaged 14 and 17 insects per tree respectively. About the same amount of infestation had been observed in both plantations the year before and the year after these counts. At such population levels, the shoot moth is not likely to miss laying eggs on any trees (9) or any leaders.

Population Levels Early in the Generation

When the internodal distances were measured in the four youngest plantations (springs of 1958 and 1959), it was obvious that more insects were on damaged trees than on undamaged trees. This raised the question whether (1) more eggs were laid on damaged trees or (2) the same number of eggs were laid on both kinds of trees, but more early larval mortality occurred on the undamaged trees. Accordingly, the number of eggs on undamaged and damaged trees were compared in these four plantations.

This comparison was in terms of mean number of eggs on the entire tree and mean number of eggs per shoot. Whole-tree egg counts represent parts of many trees put together to make a composite sample tree. The number of whorls and the number of branches per whorl had been counted on about 50 damaged trees in each plantation, and the mean number of internodes and number of branches per whorl were taken as an estimate of the typical tree. Then, starting at a random point on the area, one branch corresponding to a branch on the typical tree was removed from each of a series of succeeding trees. Thus not more than one branch came from the same tree. Eggs on these branches were counted in the laboratory. In the shoot samples, one of the top-whorl shoots most nearly corresponding to a predetermined cardinal direction was removed from each of 10 to 30 damaged trees and examined in the laboratory for eggs. The same procedures were used on similar numbers of undamaged trees.

The numbers of eggs deposited varied considerably, but they did not indicate that more eggs tended to be laid on damaged trees than on undamaged ones (table 1). The work of Green et al. (4) also indicates that ovipositing females tend to disperse, thereby increasing the probability of all trees being infested.

Table 1.--Numbers of shoot moth eggs found per tree and per shoot in the four youngest plantations. Observations made in 1958 and 1959.

Plantation	Mean no. eggs per tree		Mean no. eggs per shoot	
	Undamaged trees	Damaged trees	Undamaged trees	Damaged trees
1	---	---	2.1 ± 1.9	1.7 ± 2.3
2	122 ± 52	44 ± 31	---	---
3	124 ± 9	168 ± 5	0.9 ± 0.9	0.4 ± 0.8
4	20 ± 9	110 ± 57	---	---

Minimum growth of undamaged trees exposed to attack

The problem was to explain why, in spite of uniform insect attack, some groups of trees were severely damaged while others were not. Inspection of trees in such areas suggested that different growth rates were involved, irrespective of any growth reduction which the insect caused. Some actual growth rates are plotted in figure 4; these show that the undamaged trees were twice as tall as the damaged ones.

It was reasoned that computing the least annual rate of growth of undamaged trees during a period of high shoot moth intensity in each of the four younger plantations would give a value near the minimum at which normal growth might be expected to proceed despite shoot moth abundance. Therefore, the earliest year of severe damage to 50 percent or more of the trees eventually damaged (year "x" in this discussion) was ascertained in each plantation, and the mean internodal growth for the next year ($x \pm 1$) on the fast-growing trees was computed.

A slow-growing tree was considered severely injured in a given year if adventitious buds had developed that year, if a distortion in the stem was present, or if no more than one lateral bud of the leader cluster survived. Reduction in number of branches per whorl is an excellent index of shoot moth intensity (figs. 4, 5, and 6).

The internodal growth of year $x + 1$ rather than that of year x was measured on fast-growing trees for several reasons: Intensity of attack greater than 50 percent was registered in year $x + 1$ by slow-growing trees, indicating further insect buildup; and an additional year's opportunity was thereby available for the insect to damage fast-growing trees, thus reducing the probability of the insect's chance failure to attack them.

During the year of maximum shoot moth attack, the internodal distances of undamaged trees in the study plots on the four plantations containing groups of damaged and undamaged trees averaged as follows: 14.1 ± 2.9, 14.9 ± 2.4, 18.2 ± 2.0, and 18.3 ± 4.9 inches. By analysis of variance and t tests, the means 14.1 and 14.9 were significantly different from the means 18.2 and 18.3, but not from each other. Mean annual internodal growth of these undamaged trees increased in subsequent years. Therefore, a mean of 14.1 inches was the least amount of yearly growth associated with lack of damage on trees amply exposed to shoot moth attack.

An annual growth rate of 15 inches for the first 5 years after breast height in red pine indicates a site index of 55 by the 5-year intercept method (1). The four oldest plantations in this study actually had site indexes ranging from 55 to 70 by the intercept method. The two which have never been damaged by the insect had attained a growth rate of approximately 15 inches or more per year only 5 years after they were planted (fig. 5) and they reached a nonsusceptible condition before the insect had time to build up. The remaining two older plantations were apparently slower growing and did not attain the 15-inch yearly growth rate until several years later (fig. 6).

The rate of red pine growth can be affected by site quality, planting method, competition, genotype, and other factors. However, site quality is thought to be the factor most often influencing the growth rate of red pine plantations. Red pine on sites where the growth rate is unusually slow provides striking evidence of the influence of site quality. For example, plantings on sterile strip-mine spoil banks are especially susceptible (8) as are plantings on eroded sand dunes such as those in western Michigan (fig. 7).

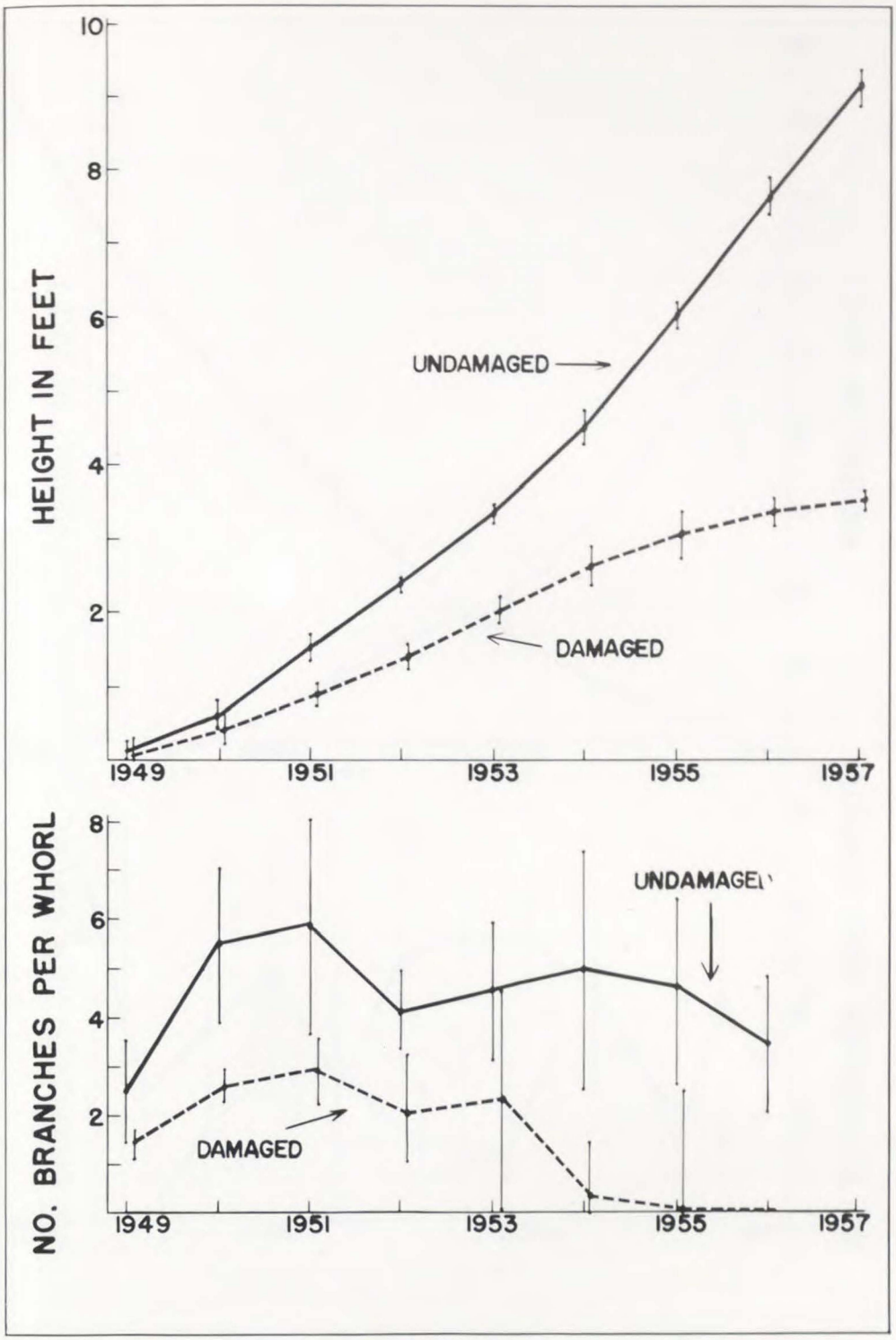

Figure 4.--Mean height and number of branches per whorl of adjacent damaged (---) and undamaged (——) trees, 1949-1957. Vertical bars show one standard deviation.

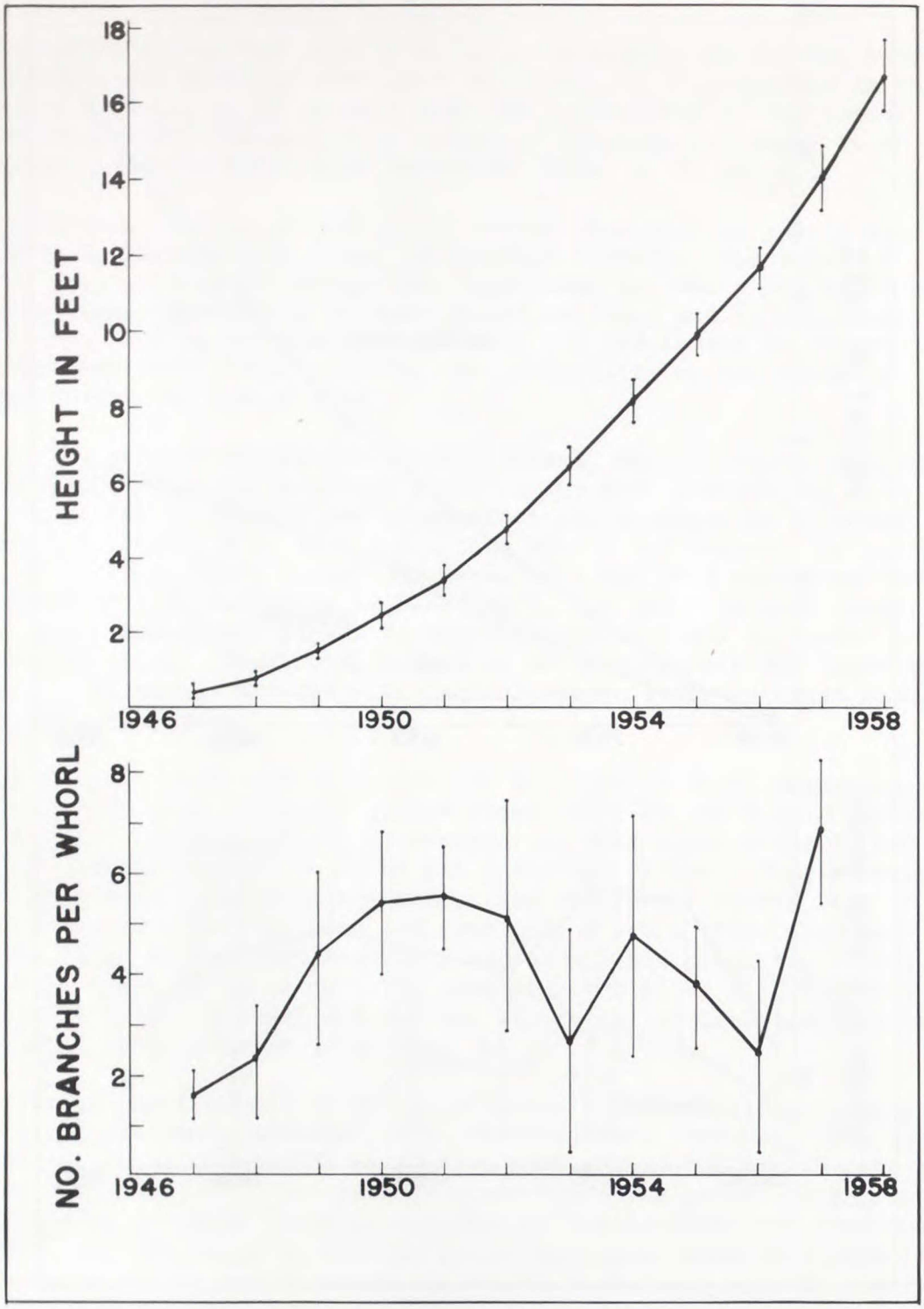

Figure 5.--Mean height and number of branches per whorl in a plantation infested but never damaged by the shoot moth. Vertical bars show one standard deviation.

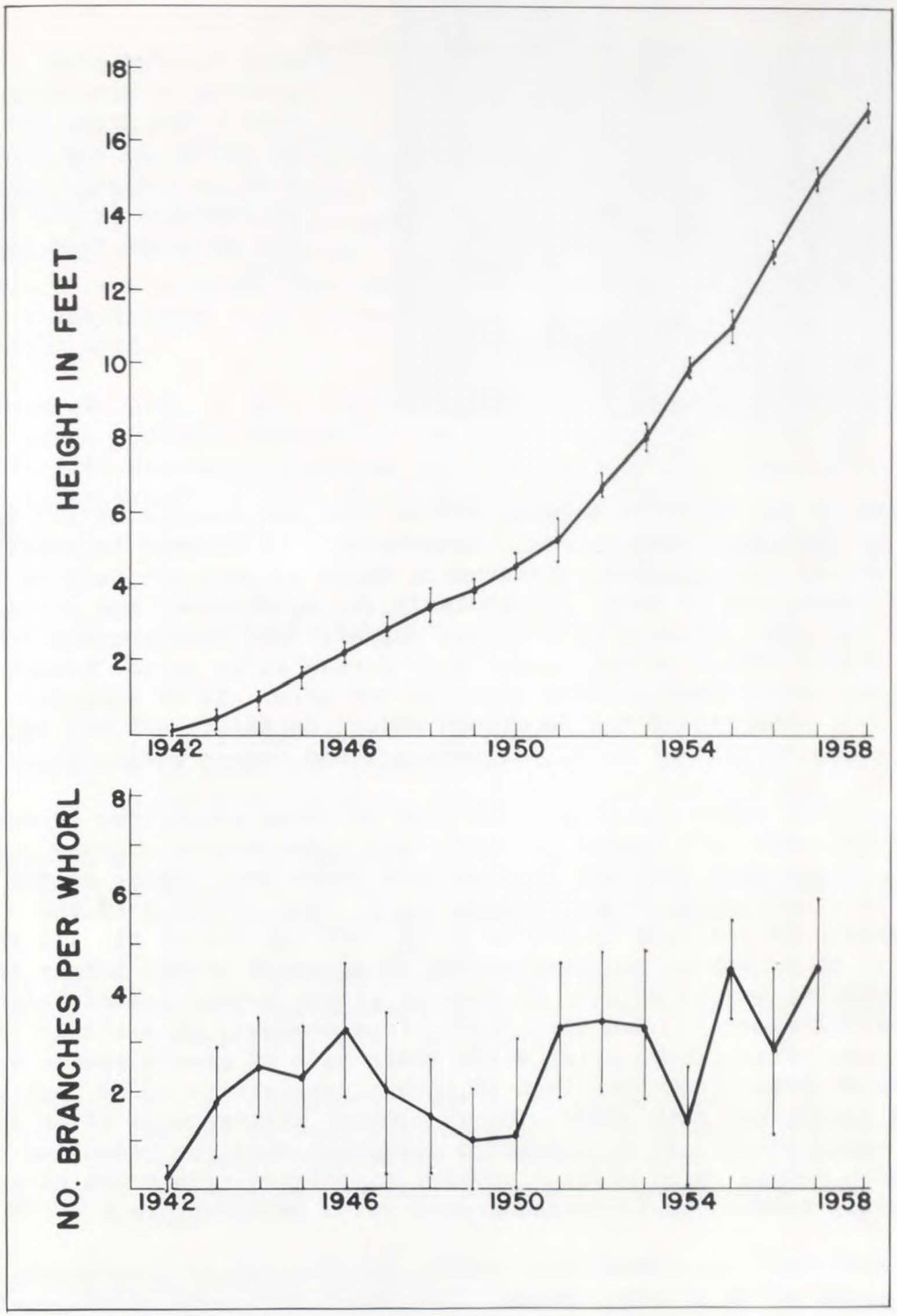

Figure 6.--Mean height and number of branches per whorl in a plantation which recovered from shoot moth damage. Vertical bars show one standard deviation.

Figure 7.--Red pine growing on windblown sand. The trees are 13 years old and have been perennially infested by damaging levels of the European pine shoot moth.

The basis of the relation between growth rate and susceptibility to damage by the shoot moth is still uncertain. Differences in growth rates reflect physiological differences which in turn are related to various components of site, particularly the nutritional and moisture factors (6, 12). Studies in progress suggest that fast-growing trees have a lethal effect on many shoot moth larvae early in the insect generation, which slow-growing trees do not have. It is possible that growth rate itself has no direct effect on the insect but is merely a concomitant of an as yet unrecognized insect mortality factor.

The results of other investigations seem to offer supporting evidence that growth rate is a factor in shoot moth infestations of very young trees. It has been observed that serious shoot moth damage seldom occurs in stands after crown closure (3, 5, 11). Studies of the early growth of red pine by Ferree et al. (2) and Day et al. (1) show that rate of growth in red pine before trees reach breast height (pre-establishment) is not related to rate of growth beyond breast height (post-establishment). Red pine plantations commonly grow slowly till they become established, after which their rate of growth speeds up. Such stands often grow less than 15 inches per year at first, but more than 15 inches per year later. Crown closure follows soon after stands become established. It is therefore suggested that the reduction of shoot moth damage which earlier workers associated with crown closure is actually related to increased growth rates in older trees.

Rarely were red pine stands seen where, despite yearly internodal growth rates of 15 or more inches, high shoot moth population levels had developed. Such stands were seen so infrequently that their existence is not considered to alter the practical application of growth rate as an indicator of susceptibility.

Conclusions

It is concluded that red pine attaining a growth rate of 15 inches or more a year before and after establishment will not be seriously damaged by the shoot moth (figs. 2 and 5). Trees that grow less than 15 inches a year before establishment but more than 15 inches after establishment will tend to recover from shoot moth attack (figs. 3 and 6). Finally, trees growing less than 15 inches a year both before and after establishment will be perennially susceptible to damage by the shoot moth.

Although red pine is more susceptible to shoot moth attack than other pines commonly planted in the Lake States (10), it is not necessary to recommend planting the less susceptible pines where red pine is likely to grow 15 or more inches per year.

Literature Cited

(1) Day, M. W., C. F. Bey, and V. J. Rudolph.
1960. Site index for planted red pine by the 5-year growth intercept method. Jour. Forestry 58: 198-202.

(2) Ferree, M. J., T. D. Shearer, and E. L. Stone.
1958. A method of evaluating site quality in young red pine plantations. Jour. Forestry 56: 328-332.

(3) Friend, R. B., G. H. Plumb, and H. W. Hicock.
1938. Notes on the European pine shoot moth in Connecticut. Jour. Econ. Ent. 31: 506-513.

(4) Green, G. W., W. F. Baldwin, and C. R. Sullivan.
1957. The use of radioactive cobalt in studies of the dispersal of adult females of the European pine shoot moth, Rhyacionia buoliana (Schiff.). Canad. Ent. 89: 379-383.

(5) Hawley, R. L., and H. J. Lutz.
1943. Establishment, development, and management of conifer plantations in the Eli Whitney Forest, New Haven, Connecticut. Yale Univ. Sch. Forestry Bul. 53, 81 pp.

(6) Heiberg, S. O., L. Leyton, and H. Loewenstein.
1959. Influence of potassium fertilizer level on red pine planted at various spacings on a potassium-deficient site. Forest Sci. 5: 142-153.

(7) Heikkenen, H. J.
1960. The identification and dating of past attacks of the European pine shoot moth (Rhyacionia buoliana (Schiff.)) on red pine (Pinus resinosa Ait.). Jour. Forestry 58: 380-384.

(8) Limstrom, G. A.
1960. Forestation of strip-mined land in the Central States. U.S. Dept. Agr. Handbook 166, 74 pp.

(9) Miller, W. E.
1960. The European pine shoot moth: relationship between proportion of trees infested and number of insects per tree. Jour. Forestry 58: 647-648, illus.

(10) Miller, W. E., and H. J. Heikkenen.
1959. The relative susceptibility of eight pine species to European pine shoot moth attack in Michigan. Jour. Forestry 57: 912-914.

(11) Miller, W. E., and R. B. Neiswander.
1955. Biology and control of the European pine shoot moth. Ohio Agr. Expt. Sta. Bul. 760, 31 pp.

(12) Stone, E. L., G. Taylor, N. Richards, and J. Dement.
1958. Soil and species adaptation: red pine plantations in New York. First North Amer. Forest Soils Conf., 1958: 181-184.